PATENT SPECIFICATION

DRAWINGS ATTACHED

Inventor: ALWYN FREDERICK STAGLES

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Int. Cl.:—**G 01 s 7/40**//H 01 q

COMPLETE SPECIFICATION

Radar Target Simulators

We, ELLIOTT BROTHERS (LONDON) LIMITED, a Company organised under the laws of Great Britain of Century Works, Lewisham, London, S.E. 13, do hereby declare the innvention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to radar target simulators, and to the use of such simulators to test the performance of radar systems.

There are at present two methods for testing the performance of radar systems. According to the first method, separate measurements are made of the electrical power of the transmitter of the radar system and of the sensitivity of the receiver of the radar system, both of these measurements tending to be inaccurate unless the radar aerial of the radar system can be replaced, in turn, by a bolometer and by a calibrated generator or noise tube. According to the second method, a resonant cavity or so-called "echo box" is employed to simulate radar echos: this method is unsatisfactory as it involves the use of a pulse-shape which is not employed in real use and which may saturate the receiver of the radar system during much of the operating period of the receiver.

According to the invention, a radar target simulator is provided which is suitable for testing a radar system under conditions closely similar to those encountered in actual use: such testing does not depend upon the accurate measurement of electrical power, but merely upon a comparison of the amplitudes of two electrical pulses. Furthermore, the long-term accuracy of the simulator can be made to depend only upon the calibration of attenuators which can be made to be very stable in operation.

According to the invention, there is provided a non-regenerative radar target simulator which includes receiving means for receiving radar pulses, first frequency-changing means operable to convert the received pulses into coherent pulses at an intermediate frequency, a delay unit adjustably operable to delay the pulses at the intermediate frequency by a predetermined interval of time to simulate the effect of target range, second frequency-changing means phase locked to the first frequency-changing means operable to convert the delayed pulses into coherent pulses at the frequency of the said radar pulses, amplitude-modifying means operable to control the amplitude of the delayed pulses at the radar frequency to simulate the effects of target range and/or target size, and transmitting means for transmitting the amplitude-controlled delayed coherent pulses at the radar frequency.

Preferably, the said receiving means and the said transmitting means comprises a single radar aerial.

The radar target simulator preferably includes control means supplied with the said coherent pulses at the frequency of the said radar pulses, before those coherent pulses are supplied to the amplitude modifying means, the control means being arranged to control the amplitude of those coherent pulses in a fixed relationship to the amplitude of the said received radar pulses. In such case, the control means may include an amplifier with automatically variable gain which gain is automatically varied according to the relative amplitudes of the said coherent pulses at the frequency of the said

radar pulses, before those coherent pulses are supplied to the amplitude-modifying means, and of the said received radar pulses; such an amplifier may be connected to the output of the delay unit.

Where the control means is provided, it may include a comparator arranged to respond to both the said coherent pulses at the frequency of the said radar pulses, before those coherent pulses are supplied to the amplitude-modifying means, and also the said received radar pulses, the comparator being arranged to deliver an error signal representing the difference in amplitude of the two signals supplied to it; in such case, the error signal may be arranged to automatically control the automatically variable gain of the amplifier.

The delay unit may be of the mercury-type, comprising an input transducer and an output transducer mounted within a vessel containing mercury, and a reflector of which the position within the vessel is adjustable to change the time delay introduced by the delay unit.

The amplitude-modifying means may comprise at least one variable attenuator, at least one of which may be of the rotary-vane type. There may be two variable attenuators of which one is variable to simulate the effect of change of target range and the other is variable to simulate the effect of change of target size.

The radar target simulator may include synchronising means for varying the delay of the delay unit in synchronism with the amplitude-modifying means, so as to simulate the effect of changes of target range both as regards delay and attenuation of the radar pulses involved The synchronising means may comprise means for varying the said one variable attenuator in synchronism with the delay of the delay unit, and may include a servomechanism. The synchronising means may be arranged to vary the said one variable attenuator by means of a cam.

The radar target simulator may include an automatic-frequency-control circuit arranged to tend to maintain the intermediate frequency constant.

Preferably, the said intermediate frequency is a second intermediate frequency, the first frequency-changing means including a first frequency-changer arranged to convert the said received pulses into coherent pulses at a first intermediate frequency and including a second frequency-changer arranged to receive the pulses at the first intermediate frequency and to convert those pulses into the said coherent pulses at the second intermediate frequency, and the second frequency-changing means including a third frequency-changer arranged to convert the said delayed pulses from the delay unit into second coherent pulses at the first intermediate frequency and including a fourth frequency-changer arranged to receive the said second coherent pulses and to convert those pulses into the said coherent pulses at the frequency of the said radar pulses.

One embodiment of the invention will now be described by way of example, reference being made to the accompanying drawings, of which:—

Figure 1 is a block-diagram of a radar target simulator according to the invention;

Figure 2 is a view, partly broken away, illustrating the use of the simulator of Figure 1 to test the performance of the radar system of an aircraft, and

Figure 3 is a view, partly broken away, of an alternative form of aerial structure for a simulator according to the invention.

Referring to Figure 1, the radar target simulator includes an aerial 1, in the form of a horn, arranged to receive from a radar system (not shown) radar pulses in the form of a train of pulses of a suitable repetition rate and at a radar frequency which may be, for example, of the order of 10,000 Mc/s. These pulses are passed from the aerial 1 to a directional coupler 2 which routes the pulses both to a monitor diode 3 and, through a waveguide 4, to a ferrite Y-junction circulator 7 which has also another input, 5, and an output 6.

The monitor diode 3 is of known form, and is employed both to display the pulse-shape of the radar pulses and also to monitor the peak power of the radar pulses.

The circulator 7 is also of known form, and has the property that if radar pulses are supplied along the waveguide 4, such pulses are routed to the output 6. Similarly, if radar pulses are supplied to the other input 5, such pulses are routed to the waveguide 4.

The radar pulses supplied to the waveguide 4 are thus routed to the input of a 40 db. fixed attenuator 11 the output of which is connected to the input of a 20 db. fixed attenuator 12. The output of the attenuator 12 is supplied to the input of a first frequency-changer 13 in the form of a microwave mixer which is also supplied, from a microwave local oscillator 14 which includes a klystron, with microwave oscillations at a frequency variable within the range of, say, 7,000—12,600 Mc/s. The latter frequency is so chosen, with regard to the radar frequency, that the output of the frequency-changer 13 includes pulses at a first intermediate frequency of 150 Mc/s, such pulses being of similar shape to, and having the same repetition rate as, the radar pulses received by the aerial 1, that is such pulses are coherent with the pulses received by the aerial 1.

These output pulses from the frequency-changer 13 are amplified by a buffer ampli-

fier 15 and are then supplied to the input of a second frequency-changer 16 in the form of a mixer which is also supplied, from a crystal-controlled local oscillator 17, with electrical oscillations at a frequency of 135 Mc/s. The latter frequency is so chosen that the output of the frequency-changer 16 includes pulses at a second intermediate frequency of 15 Mc/s, such pulses being again coherent with the radar pulses received by the aerial 1.

These output pulses from the frequency-changer 16 are amplified by a drive amplifier 18 and are then applied to the input of a delay line 19. The amplifier 18 is transistorised and is arranged to match the output of the second frequency-changer 16 to the input of the delay line.

The delay line 19 is preferably of the known mercury-type, comprising an input transducer and an output transducer mounted adjacent to one another at one end of a tube containing mercury, and a reflector the position of which within the mercury is adjustable to change the interval of time by which electrical pulses passed through the delay line are delayed. The delay interval of a mercury-type delay line may be within the range of 25 to 330 microseconds.

The output of the delay line 19 comprises pulses, at the second intermediate frequency, which are again coherent with the radar pulses received by the aerial 1; these pulses are amplified by an amplifier 30 provided with automatic gain control, and the pulses are then supplied to the input of a third frequency-changer 21 in the form of a mixer which is also supplied, from the oscillator 17, with the electrical oscillations at the frequency of 135 Mc/s. Since both the second and third frequency changers are supplied from a common oscillator they are phase locked to one another. The output of the third frequency-changer 21 thus includes pulses at the first intermediate frequency of 150 Mc/s, such pulses being again coherent with the radar pulses received by the aerial 1.

These output pulses from the frequency-changer 21 are amplified by a power amplifier 22 and are then supplied to the input of a fourth frequency-changer 23 in the form of a microwave mixer which is also supplied, from the oscillator 14, with the microwave oscillations at a frequency variable within the range of, say, 7,000—12,600 Mc/s. Since the first and fourth frequency changers are supplied from a common oscillator they are phase locked to one another. The output of the frequency-changer 23 thus includes pulses at the same radar frequency as that of the radar pulses received by the aerial 1 and, moreover, these pulses are coherent with the radar pulses received by the aerial 1.

The output of the frequency-changer 23 includes undesired components which are removed by a suitable side-band filter 24, and the remaining pulses just described pass through the filter 24 and then to the other input 5 of the circulator 7, via a target-area variable attenuator 25 connected in series with a target-range variable attenuator 26, each attenuator being of the rotary-vane type and having an attenuation variable from 10 db to 50 db. At this stage, the pulses represent the radar echo from a target, and the pulses are routed by the circulator 7 to the waveguide 4 when they pass through the directional coupled 2, without reaching the monitor diode 3, to the aerial 1. Thence, the pulses are transmitted back to the radar system (not shown).

Changes of the attenuation produced by the target-area variable attenuator 25 represent the effect of changes of area of the simulated target. Changes of the attenuation produced by the target-range attenuator 26, and changes of the delay interval introduced by the delay line 19, represent the effects of changes of range of the simulated target; the attenuation of the target-range attenuator 26, and the delay interval of the delay line 19, must therefore both be altered in suitable synchronism. Thus, in Figure 1, a servo-mechanism 31 is provided, and is arranged to control the delay interval of the delay line 19, for example by varying the position of the reflector of the mercury-type delay line; in addition, the servo-mechanism is arranged to simultaneously control the angular position of a cam 32 which controls the attenuation of the target-range attenuator 26, for example by varying the position of the rotary vane of that attenuator. The input 33 to the servomechanism may be any suitable signal which demands a given simulated target-range or a given rate of change of simulated target-range. The attenuation produced by the target-range attenuator 26 should vary as the fourth power of the simulated target-range, and the cam 32 may be shaped to this end.

The pulses which form the useful output of the drive amplifier 18 are at the second intermediate frequency of 15 Mc/s, this frequency being chosen to suit the working frequency-range of the delay line 19. Should the second intermediate frequency depart from this working frequency-range, then the delay line 19 may not operate correctly; a frequency-control circuit is therefore provided, the output pulses from the amplifier 18 being supplied to a discriminator 36 the output of which is a direct-current error signal representing in sign and magnitude the sense and magnitude of the departure of the second intermediate frequency from 15 Mc/s. This error signal is supplied to a frequency-control unit 37 which is so connected to the power-supply unit 38 of the

oscillator 14, that the frequency of the oscillator 14 automatically tends to change to a value which maintains the second intermediate frequency at 15 Mc/s; in practice, the error signal may be superimposed upon the direct-current supply to the klystron of the oscillator 14, such as to tend to change the frequency of the oscillator 14 in the appropriate sense.

The pulses at the output of the drive amplifier 18 are also supplied to the input of a cathode-ray oscilloscope 39, so that the form of the pulses can be observed.

When, in the circuit of Figure 1, the delay interval introduced by the delay line 19 is changed, this is done by changing the position of the reflector within the mercury-filled tube of the delay line 19: such adjustment, however, also changes the attenuation of the pulses passing through the delay line. To counteract such undesired changes of attenuation, the apparatus of Figure 1 is provided with an automatic-gain-control circuit which so controls the amplification of the amplifier 20 that the pulses at the output of the side-band filter 24 are of the same amplitude as the pulses at the input to the 20 db. fixed attenuator 12. Thus, a microwave hybrid-T network 41 receives both the pulses at the output of the filter 24 and the pulses at the input of the fixed attenuator 12, and supplies the combined pulses to a detector 42 which demodulates the combined pulses and supplies them to a comparator 43. The comparator 43 is also supplied with a synchronising signal; this is derived, by supplying the radar pulses at the input of the 40 db. fixed attenuator 11, through a further 40 db. fixed attenuator 44, to a detector 45 wherein the pulses are demodulated, the output of the detector constituting the synchronising signal. The output of the comparator 43 is a direct-current error signal representing in sign and magnitude the departure in amplitude of the pulses at the output of the side-band filter 24 from the pulses at the input to the fixed attenuator 12, and this error signal is supplied to a transistor amplifier 46 which acts as an infinite-impedance detector, a so-called "box-car amplifier", the output of which is employed to control the amplification of the amplifier 20.

The use and operation of the circuit of Figure 1 is illustrated by Figure 2. In Figure 2, an aircraft 47 is provided with an internal radar system at least part-located within the nose 48 of the aircraft, this radar system including an aerial 49. The apparatus of Figure 1, with the exception of the aerial 1, is located in cases 50, and is connected by means of a suitable cable 51 to an aerial structure 52 in which the aerial 1 takes the form of a horn 53. The structure 52 is tripod-mounted in front of the aircraft and includes a telescope 54 through which the aircraft 47 can be viewed, to permit the horn 53 to be aligned with the aircraft aerial 49. Alternatively, the aircraft may be sighted on to the horn 53 with the aid of a pilot's sighting mark 55. Telephonic communication between a workman near to the cases 50, and a workman within the aircraft, is maintained by way of a cable 56, and a low wall 57 of radar-wave-absorbing material may be provided behind the aerial structure 52, the wall covering the sector swept by the aircraft's radar system and serving both to reduce possible interference caused by the aircraft's radar system and also to reduce the "clutter signals" (*i.e.*, the radar echos returned to the aircraft from surrounding terrain).

Where it is desired to maintain radar silence, the arrangement just described may be modified by replacing the aerial structure 52 by a probe 60 inserted into a radar-wave-absorbing muffler 61, the probe 60 being connected to a cable 62 which replaces the cable 51.

Before testing the aircraft radar system, the radar target simulator should first be tested. For this purpose, the cable 51 is first disconnected from the horn aerial 53 (Figure 2) and is connected instead (Figure 1) to a pulse-generator 64. Radar pulses are then fed into the apparatus of Figure 1 from the pulse-generator: this permits the operation of the apparatus of Figure 1 to be checked, and permits the attenuation of the aerial cable 51 to be measured. During this test sequence, the ratio of the amplitudes of the pulses of the combined pulses received by the comparator 43 can be observed, and during the subsequent testing of the aircraft radar system this ratio should be held constant.

Thereafter, the cable 51 is disconnected from the pulse generator 64 (Figure 1) and reconnected to the horn aerial 53 (Figure 2). The aircraft radar system is then switched on, and transmits radar pulses to the horn 53; such pulses are thus received by the apparatus of Figure 1 and, as described above, for each such pulse a corresponding pulse will be returned by the apparatus of Figure 1 to the horn 53 for transmission back to the aircraft radar system. Each corresponding pulse will be coherent with and will be at the same radar frequency, as that of the pulse from which it originated. Each corresponding pulse will therefore be substantially indistinguishable from a true radar echo from an actual target since the simulation is non-regenerative, that is the same pulses as entered the simulator leave it, as opposed to a regenerative system in which the pulses entering the system are used to generate further non-coherent pulses. In other words, radar pulses received by the horn 53 are employed to synthesise a radar echo from

a simulated target having a target-range, a rate of change of target-range, and a target area, each of which quantities can be set up by predetermined settings of the apparatus of Figure 1; the synthesised radar-echo, which is locked in frequency, pulse repetition rate, and pulse-shape, to the transmitted radar pulse, is then re-transmitted by the horn 53 to the radar system under test. Furthermore, the size of the simulated target area may be varied by varying the attenuation of the target-area attenuator 25; also, the magnitude of the simulated target-range, and the rate of change of the target-range, may be varied by supplying suitable demand signals to the servomechanism 31. By supplying suitable demand signals to the servomechanism 31, the simulated target may be caused to perform predetermined manoeuvres.

A radar target simulator according to the invention thus permits the indications of target size, target-range, and rate of change of target-range, as displayed or recorded by the aircraft radar system, to be compared with the actual values of the same quantities, as set up for the simulated target by the apparatus of Figure 1.

The simulator is, of course, not limited to the testing of radar systems carried by aircraft, but may be employed for testing any radar system and also for the comparative testing of two or more radar systems.

In particular, the invention is not limited to a delay line 19 which is of the mercury-type. If a delay line operating at an intermediate frequency different from 15 Mc/s employed, then the circuit of Figure 1 may be modified accordingly.

The aerial structure 52 of Figure 2 may be replaced by the alternative aerial structure shown in Figure 3. In the structure of Figure 3, the horn aerial 53 is made movable, so as to permit simulation of the effect of change of bearing of the simulated target. Thus, the horn 53 is mounted upon a carrier 67 which is slidably movable along a rod 68, the carrier 67 being moved by means of an endless belt 69 which is driven by a motor 70 through gearing 71. The apparatus of the preceding sentence is mounted within a hollow framework 72 which is rotatable about a horizontal shaft 73 but which is normally fixed in the horizontally-extending position by removable bolts 76 which secure the framework 72 to brackets 74. As indicated by the broken lines 75, the framework 72 can be swung into a vertical position, after removal of the bolts 76.

WHAT WE CLAIM IS:—

1. A non-regenerative radar target simulator which includes receiving means for receiving radar pulses, first frequency-changing means operable to convert the received pulses innto coherent pulses at an intermediate frequency, a delay unit adjustably operable to delay the pulses at the intermediate frequency by a predetermined interval of time to simulate the effect of target range, second frequency-changing means phase locked to the first frequency-changing means operable to convert the delayed pulses into coherent pulses at the frequency of the said radar pulses, amplitude-modifying means operable to control the amplitude of the delayed pulses at the radar frequency to simulate the effects of target range and/or target size, and transmitting means for transmitting the amplitude-controlled delayed coherent pulses at the radar frequency.

2. A radar target simulator according to Claim 1, wherein the said receiving means and the said transmitting means comprise a single radar aerial.

3. A radar target simulator according to Claim 1 or Claim 2, which includes control means supplied with the said coherent pulses at the frequency of the said radar pulses, before those coherent pulses are supplied to the amplitude-modifying means, the control means being arranged to control the amplitude of those coherent pulses in a fixed relationship to the amplitude of the said received radar pulses.

4. A radar target simulator according to Claim 3, wherein the control means includes an amplifier with automatically variable gain which gain is automatically varied according to the relative amplitudes of the said coherent pulses at the frequency of the said radar pulses, before those coherent pulses are supplied to the amplitude-modifying means, and of the said received radar pulses.

5. A radar target simulator according to Claim 4, wherein the amplifier is connected to the output of the delay unit.

6. A radar target simulator according to any one of Claims 3—5, wherein the control means includes a comparator arranged to respond to both the said coherent pulses at the frequency of the said radar pulses, before those coherent pulses are supplied to the amplitude-modifying means, and also the said received radar pulses, the comparator being arranged to deliver an error signal repesenting the diffeence in amplitude of the two signals supplied to it.

7. A radar target simulator according to Claim 6 together with either Claim 4 or Claim 5, wherein the error signal is arranged to automatically control the automatically variable gain of the amplifier.

8. A radar target simulator according to any preceding Claim, wherein the delay unit is of the mercury-type, comprising an input transducer and an output transducer mounted within a vessel containing mercury, and a reflector of which the position within the

vessel is adjustable to change the time delay introduced by the delay unit.

9. A radar target simulator according to Claim 8, wherein the said intermediate frequency is approximately 15 Mc/s.

10. A radar target simulator according to any preceding Claim, wherein the amplitude-modifying means comprises at least one variable attenuator.

11. A radar target simulator according to Claim 10, wherein at least one of the variable attenuators is of the rotary-vane type.

12. A radar target simulator according to Claim 10 or Claim 11, wherein there are two variable attenuators of which one is variable to simulate the effect of change of target range and the other is variable to simulate the effect of change of target size.

13. A radar target simulator according to any preceding Claim, which includes synchronising means for varying the delay of the delay unit in synchronism with the amplitude-modifying means, so as to simulate the effect of changes of target range both as regards delay and attenuation of the radar pulses involved.

14. A radar target simulator according to Claims 12 and 13, wherein the synchronising means comprises means for varying the said one variable attenuator in synchronism with the delay of the delay unit.

15. A radar target simulator according to Claim 13 or Claim 14, wherein the synchronising means includes a servomechanism.

16. A radar target simulator according to Claims 14 and 15, wherein the synchronising means is arranged to vary the said one variable attenuator by means of a cam.

17. A radar target simulator according to any preceding Claim, which includes an automatic-frequency-control circuit arranged to tend to maintain the intermediate frequency constant.

18. A radar target simulator according to any preceding Claim, wherein the said intermediate frequency is a second intermediate frequency, the first frequency-changing means including a first frequency-changer arranged to convert the said received pulses into coherent pulses at a first intermediate frequency and including a second frequency-changer arranged to receive the pulses at the first intermediate frequency and to convert those pulses into the said coherent pulses at the second intermediate frequency, and the second frequency-changing means including a third frequency-changer arranged to convert the said delayed pulses from the delay unit into second coherent pulses at the first intermediate frequency and including a fourth frequency-changer arranged to receive the said second coherent pulses and to convert those pulses into the said coherent pulses at the frequency of the said radar pulses.

19. A radar target simulator according to Claim 18, wherein the first and the fourth frequency-changers are supplied by a first common oscillator.

20. A radar target simulator according to Claim 18 or Claim 19, wherein the second and the third frequency-changers are supplied by a second common oscillator.

21. A radar target simulator according to any one of Claims 18—20, wherein the first intermediate frequency is approximately 150 Mc/s.

22. A radar target simulator according to Claim 19 or any Claim dependent upon Claim 19, wherein the first common oscillator has a frequency substantially within the range of 7,000—12,600 Mc/s.

23. A radar target simulator according to Claim 22, wherein the first common oscillator includes a klystron.

24. A radar target simulator according to Claim 20 or any Claim dependent upon Claim 20, wherein the second common oscillator has a frequency of approximately 135 Mc/s.

25. A radar target simulator according t Claim 18 together with Claim 19 or any Claim dependent upon Claim 19, wherein the automatic-frequency-control circuit includes a discriminator arranged to give an error signal in respnose to a departure of the second intermediate frequency from a predetermined value, this error signal being arranged to control the frequency of the first common oscillator in the sense to tend to maintain the second intermediate frequency constant.

26. A radar target simulator according to Claim 1 or any Claim dependent upon Claim 1, which includes a Y-junction circulator arranged to route the received radar pulses from the radar aerial to the first frequency-changing means, and arranged to route the said amplitude-controlled delayed pulses from the amplitude-modifying means to the radar aerial.

27. A radar target simulator according to any one of Claims 1 to 17 in which the first and second frequency changing means are supplied by a common oscillator or oscillators.

28. A radar target simulator according to Claim 2 or any claim dependent thereon which includes means for changing the position of the radar aerial to thereby simulate the effect of changes of the bearing of the target.

29. A non regenerative radar target simulator substantially as described herein with reference to the accompanying drawings.

For the Applicants,
RAWORTH, MOSS & COOK,
Chartered Patent Agents,
38, Sydenham Road, Croydon, Surrey, and
75, Victoria Street, Westminster,
London, S.W.1.

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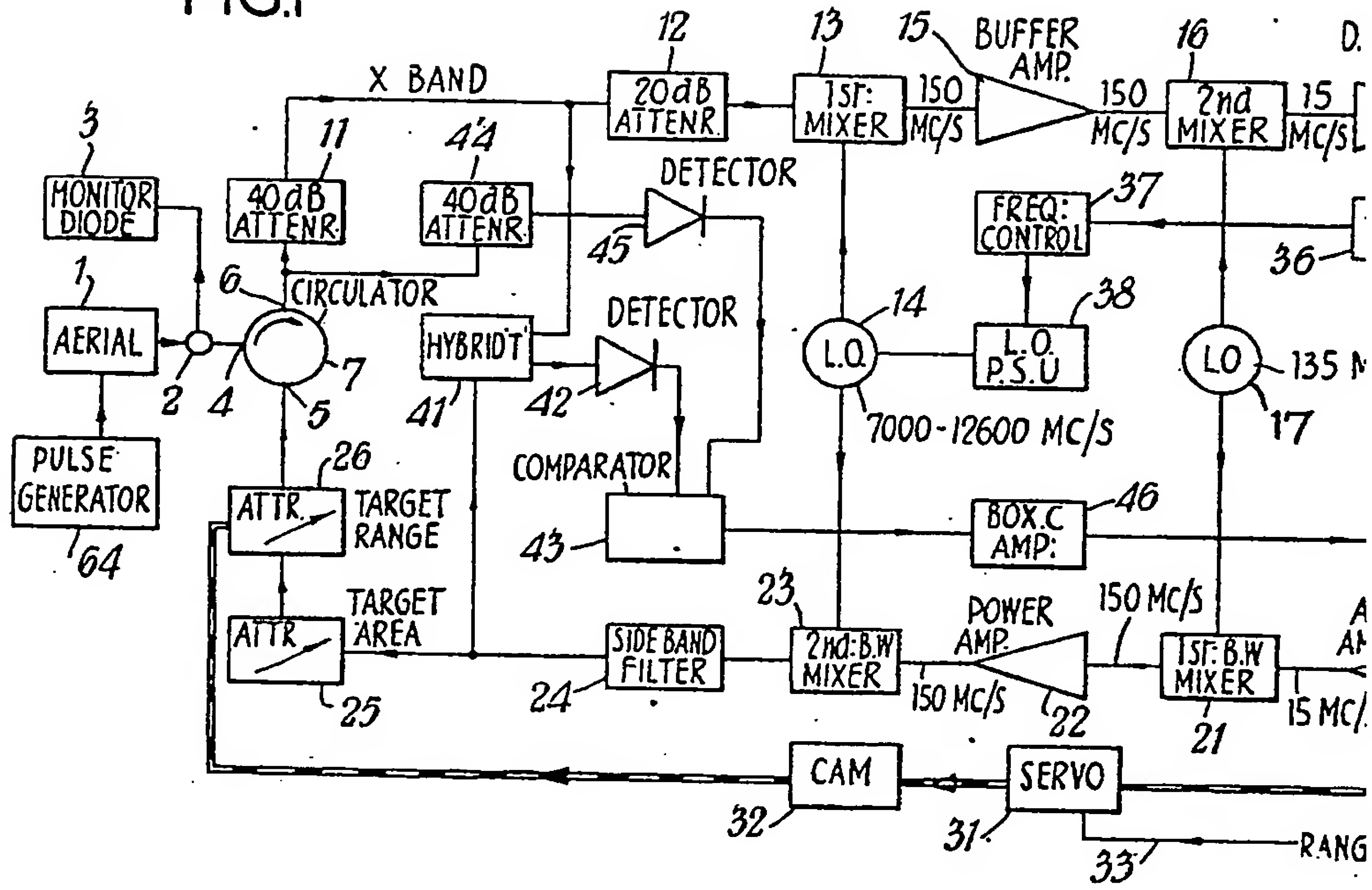
FIG.1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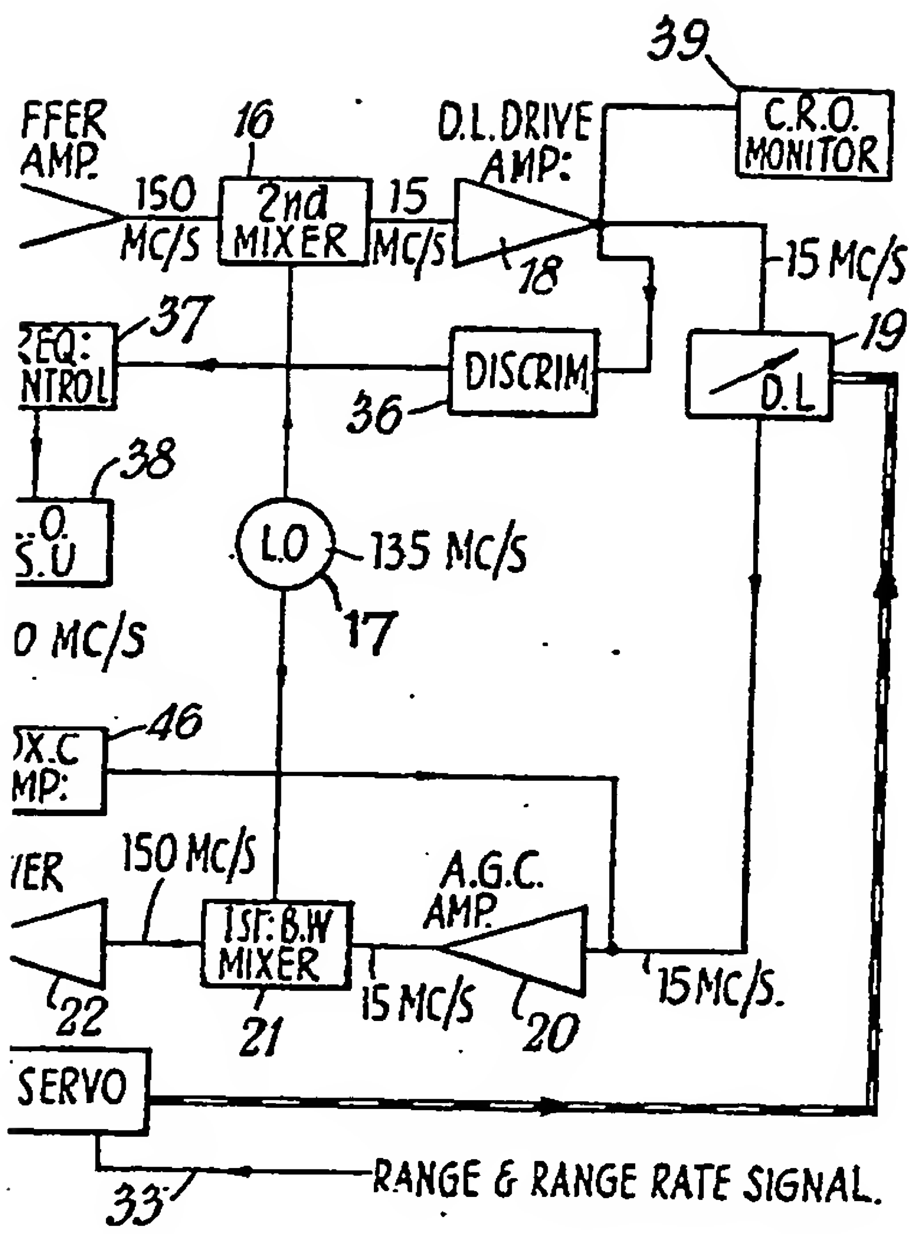
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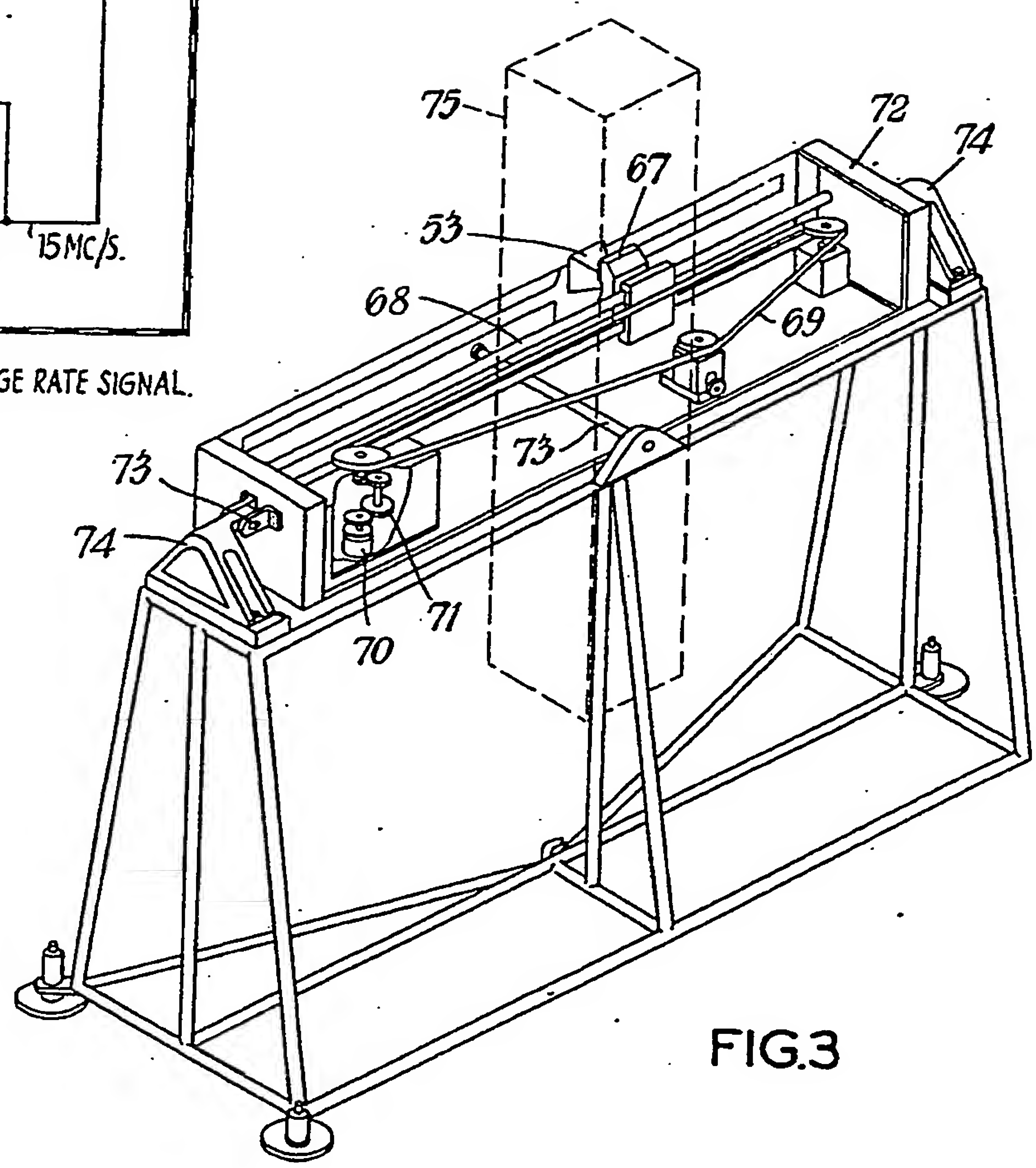
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FIG.3

1085071 COMPLETE SPECIFICATION

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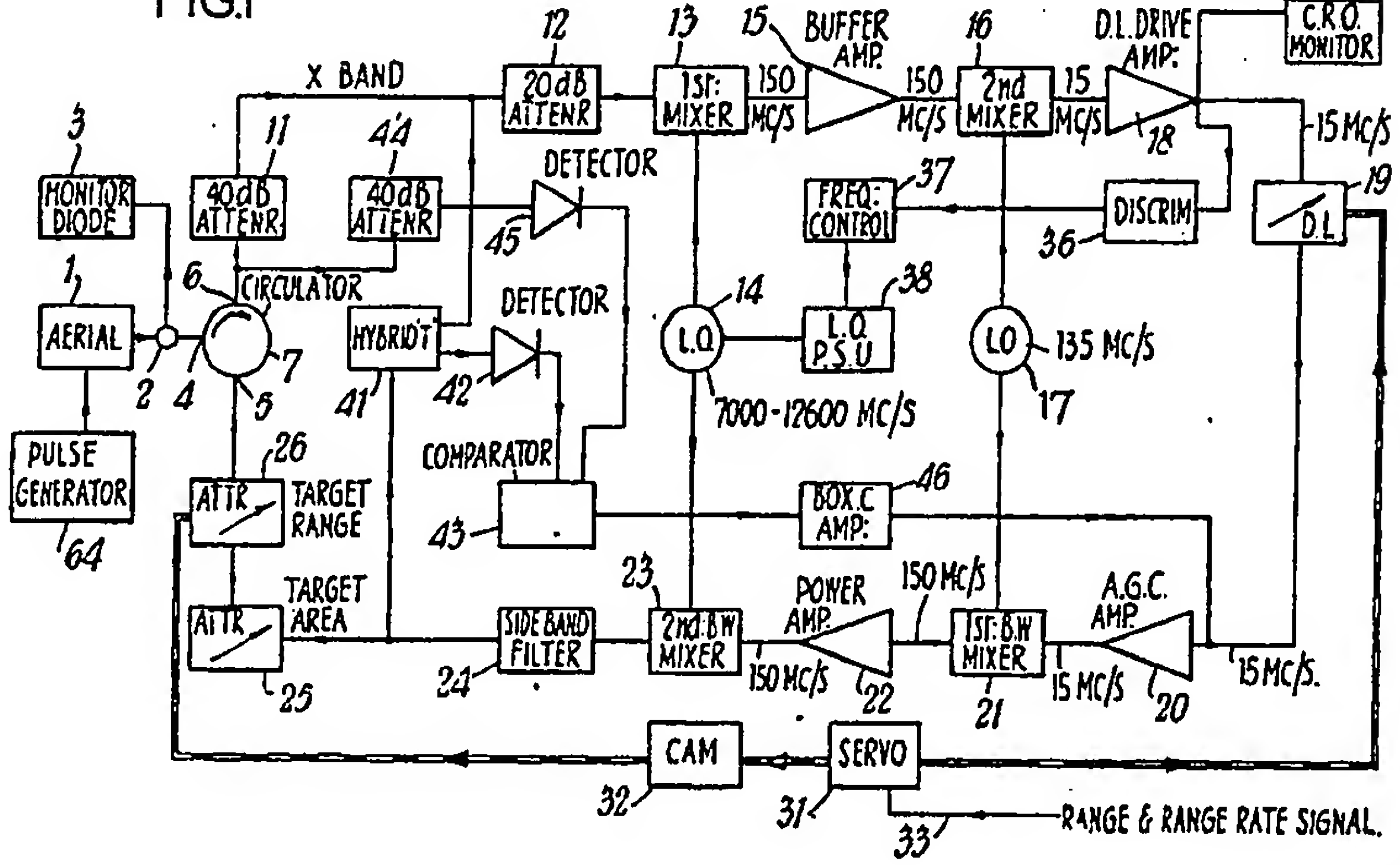
Sheet 1

FIG.1



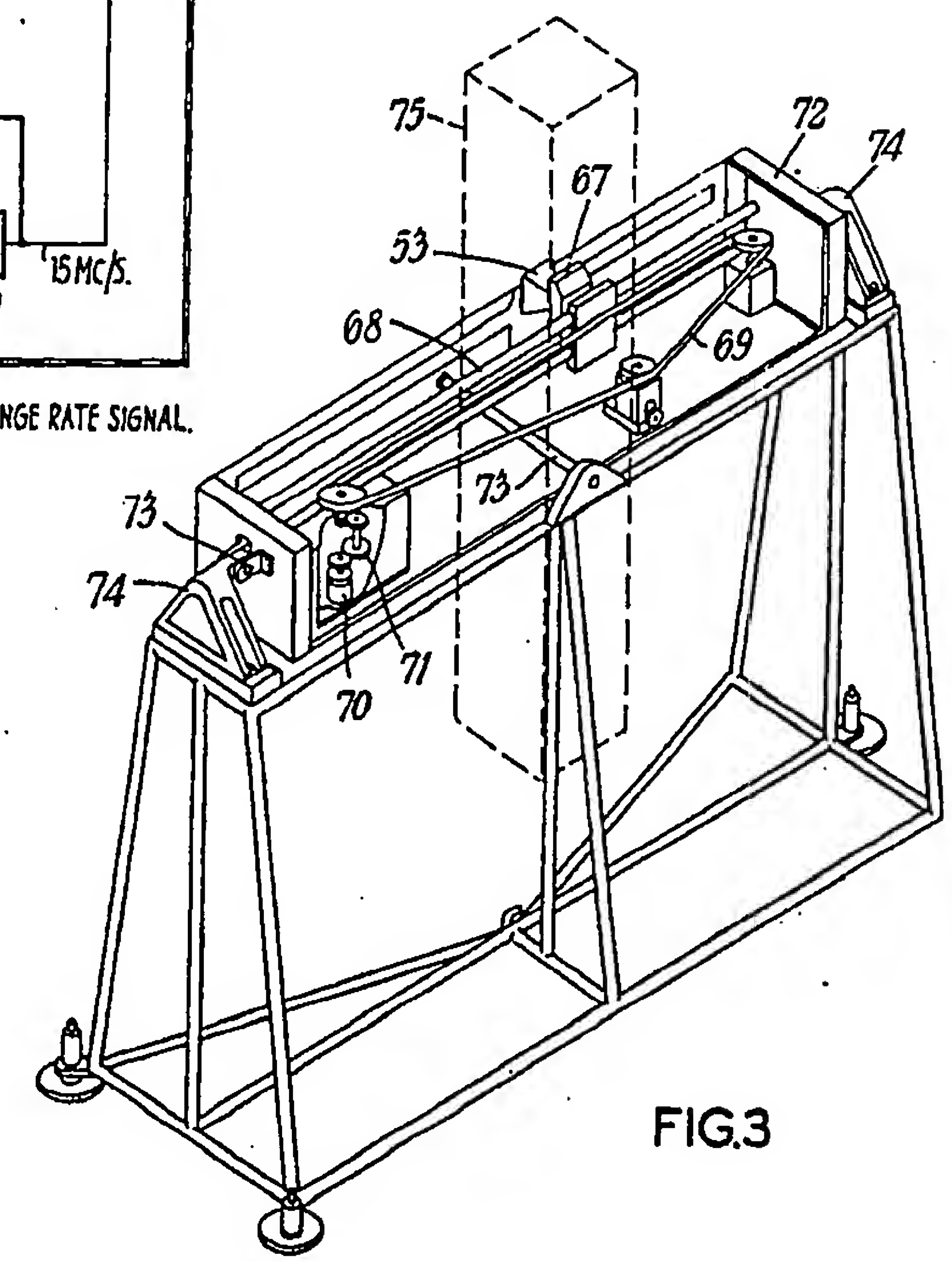


FIG.3

1085071 COMPLETE SPECIFICATION

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Sheet 2

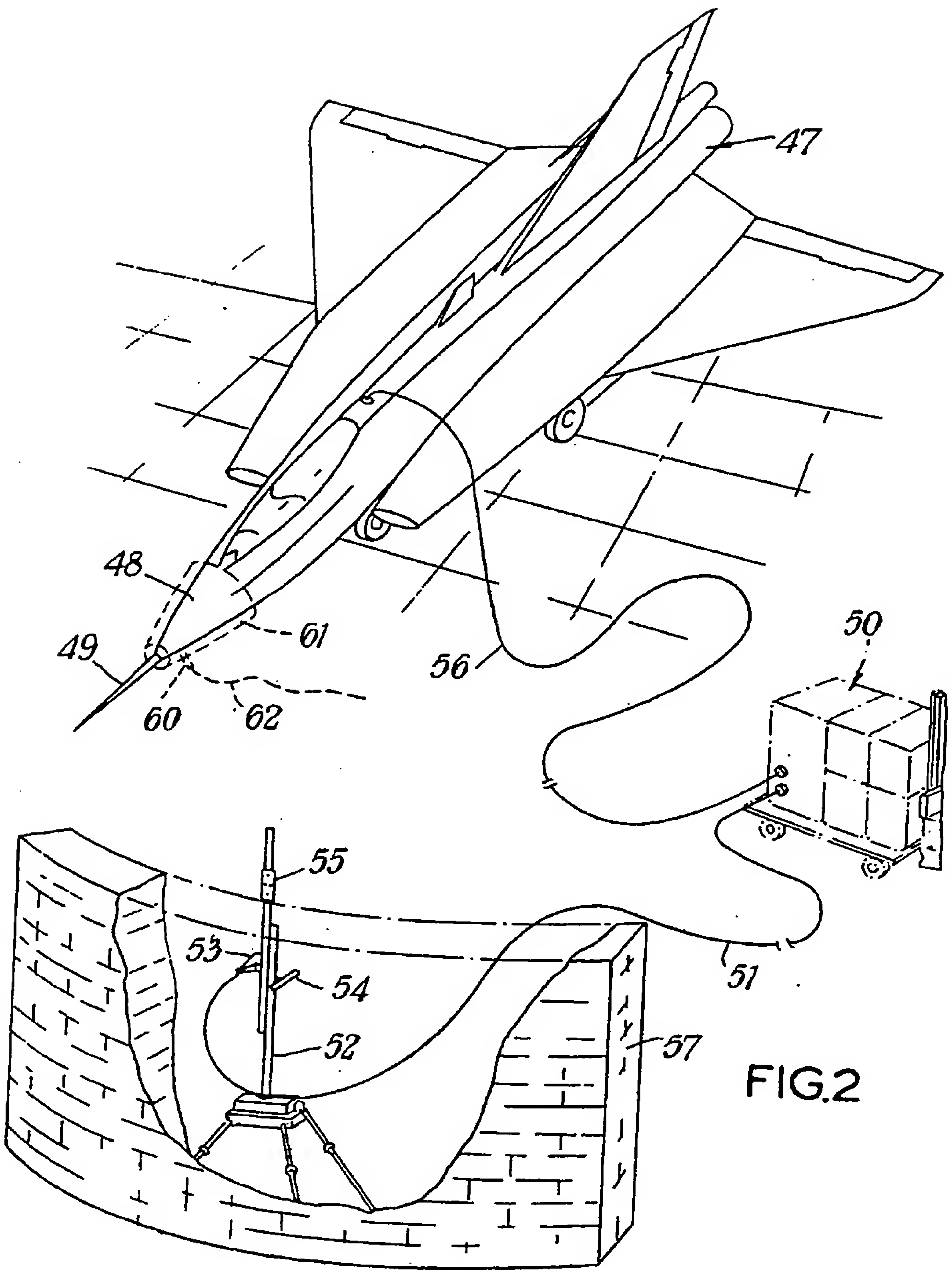

FIG.2